Cooperative Lookup

Forwarding Database

Old Index

Next Hop, New Index

FIG. 2

Non-Cooperative Lookup

Forwarding Database

Destination Address

Next Hop

FIG. 1

2/28

T	Schemes	Applicability	Lookup Time	Memory	Update Time	Multicast
N	Patricia	1st, 2nd upto Last Hop Router	$O(\log(n))$	Low	Low	No
O	DP Trie	1st, 2nd upto Last Hop Router	$O(\log(n))$	Low	Low	No
N	LPCTrie	1st, 2nd upto Last Hop Router	$O(\log^*(n))$	High	Low	Yes
C	Lulea	1st, 2nd upto Last Hop Router	$<<0(\log(n))$	Low	High	No
O	CAM	1st, 2nd upto Last Hop Router	$O(1)$	–	High	Yes
P	DRAM	1st, 2nd upto Last Hop Router	$O(1)$	High	High	No
C	Tag Switching	2nd upto Last Hop Router	$O(1)$	High	High	Yes
O	MPLS	2nd upto Last Hop Router	$O(1)$	High	High	Yes
P	IP Switching	2nd upto Last Hop Router	$O(1)$	High	High	Yes
H	CLUE	2nd upto Last Hop Router	$O(1)$	High	Low	No

FIG. 3

APPROVED BY DRAFTSMAN — O.G. FIG. CLASS SUBCLASS

FIG. 4

Router R1

In Index	Dest Prefix, Next Hop	Out Index
2	128/8, Link 1	4

Link 1 → 4

Router R2

In Index	Dest Prefix, Next Hop	Out Index
4	128.0/9, Link 1	3
4	128.128/9, Link2	6

3 — Link 1
6 — Link 2

FIG. 5

Destination Address	Cluster Number	Data
144.16.192.1	3	Data

12   14   16

10

FIG. 6

Cluster Number (Incoming)

CAST Router

Cluster Number (Outgoing)

FIG. 7

Router "218.0.1.1"

23/8	L2	1
54/8	L1	Null
205.2.10/24	L3	5

Cluster1 (Incoming)

| 203/8 | L4 | 3 |

Cluster2 (Incoming)

| 144/8 | L3 | 9 |
| 200.0/16 | L1 | 8 |

Cluster3 (Incoming)

FIG. 8

Prefix Entry	Next Hop Link	Cluster Number (Outgoing)
144/8	L3	9

FIG. 9

Routing Table

Packet

Non-Cooperative Lookup (e.g. Patricia Trie)

FIG. 10A

Routing Table

Packet

CAST Lookup

FIG. 10B

Routing Table

Packet

Cooperative Lookup (e.g. Tag Switching)

FIG. 10C

Prefix	Next Hop Link	Cluster Number (Outgoing)
0000*	L2	2
00010*	L3	3
00011*	L2	2
1000*	L1	4
100100*	L2	1

FIG. 12

FIG. 13

Technique	Applicability
Patricia	2nd upto Last Hop Router
Symmetric	1st, 2nd upto Last Hop Router
Link	2nd upto Last Hop Router

FIG. 11

FIG. 15

FIG. 14

FIG. 16

Destination Address of Packet

First Four Bits

0000 — Cluster 1 (Incoming) — 0000

0001 — Cluster 2 (Incoming) — 0001 — 0 / 1

1000 — Cluster 9 (Incoming) — 1000

1001 — Cluster 10 (Incoming) — 1001 / 00

1111 — Cluster 16 (Incoming) — 1111

FIG. 17

L1 • 1000

Cluster 1 (Incoming)

L2 000 100100

Cluster 2 (Incoming)

L3 • 00010

Cluster 3 (Incoming)

FIG. 18
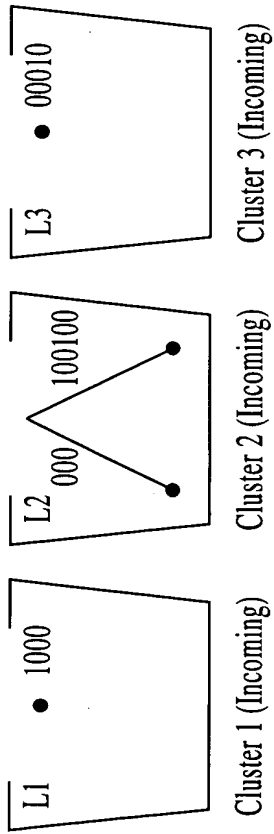
000* | L2 | 2

00011* | L2 | 2

0000* | L2 | 2

FIG. 19

A

B

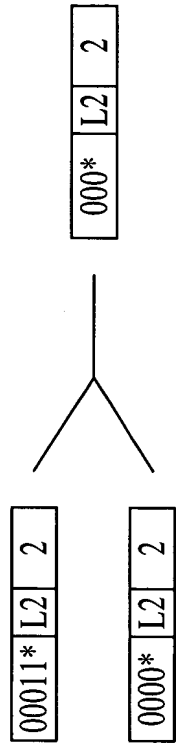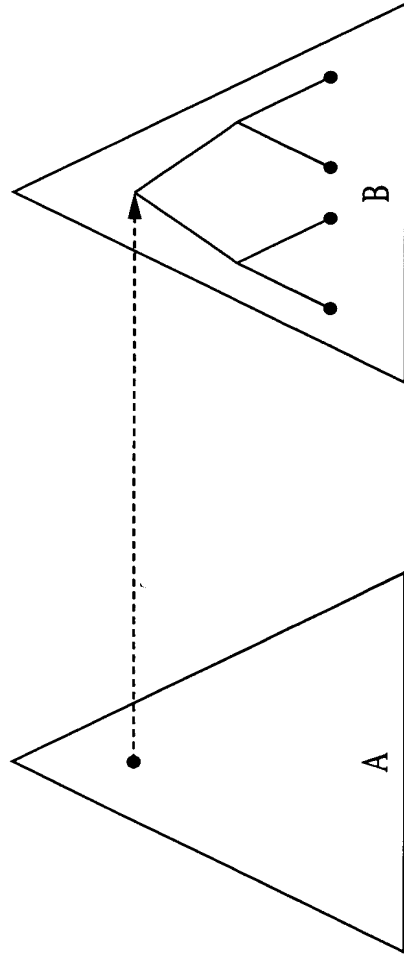**FIG. 20A**

DATA STRUCTURE

struct CAST_ROUTING_TABLE
{

PREFIX_TABLE PT
CONFLICT_TABLE CT
CLUSTER_TABLE_INCOMING CTI
CLUSTER_TABLE_OUTGOING CTO
NEXTHOP_TABLE NT

}

TABLES

PREFIX TABLE

CHILD	PREFIX	SKIP	POINTER (TO LEFT CHILD OR CLUSTER TABLE (OUTGOING) OR CONFLICT TABLE)
...	...	...	...
1 bit	1 bit	5 bits	17 bits

CONFLICT TABLE

POINTER (TO LEFT CHILD)	POINTER (TO CLUSTER TABLE (OUTGOING))
...	...
15 bits	17 bits

CLUSTER TABLE (INCOMING)

PATRICIA START LENGTH
...
5 bits

CLUSTER TABLE (OUTGOING)

CLUSTER NUMBER (OUTGOING)	POINTER (TO NEXT HOP TABLE)
...	...
17 bits	7 bits

NEXTHOP TABLE

NEXTHOP
...
32 bits

FIG. 20B

```
Procedure: CAST_Forward_Packet(Packet packet)
Upon receiving an unicast packet this procedure is called in a CAST router
begin
  if((packet.cluster.no.incoming = 'Null)  or  packet.cluster_no_incoming doesn't exist) then          **Symmetric Clustering**
    cluster_no_symmetric        ← Binary_to_decimal(packet.destination, symmetric_start_length)
    pointer_cluster_outgoing    ← Search_prefix_table(cluster_no_symmetric, symmetric_start_length, packet.destination, PT, CT)
    cluster_no_outgoing         ← CTO[pointer_cluster_outgoing].cluster_no_outgoing
    pointer_nexthop             ← CTO[pointer_cluster_outgoing].pointer_nexthop
    nexthop                     ← NT[pointer_nexthop].nexthop
    Sendpacket (cluster_no_outgoing, nexthop)
  else                                                                                                   **Patricia Clustering**
    patricia_start_length       ← CTI[packet.cluster_no_incoming]
    pointer_cluster_outgoing    ← Search_prefix_table(packet.cluster_no_incoming, patricia_start_length, packet.destination, PT, CT)
    cluster_no_outgoing         ← CTO[pointer_cluster_outgoing].cluster_no_outgoing
    pointer_nexthop             ← CTO[pointer_cluster_outgoing].pointer_nexthop
    nexthop                     ← NT[pointer_nexthop].nexthop
    Sendpacket (cluster_no_outgoing, nexthop)
  endif
end
```

FIG. 20C

DATA STRUCTURE

```
struct CAST_ROUTING_TABLE
{
    LINK-PREFIX_TABLE PT
    CONFLICT_TABLE CT
    CLUSTER_TABLE_INCOMING CTI
    CLUSTER_TABLE_OUTGOING CTO
}
```

FIG. 21A

TABLES

LINK-PREFIX TABLE

CHILD	PREFIX	SKIP	POINTER (TO LEFT CHILD or CLUSTER TABLE (OUTGOING) or CONFLICT TABLE)
...	...	...	...
1 bit	1 bit	5 bits	17 bits

CLUSTER TABLE (OUTGOING)

CLUSTER NUMBER (OUTGOING)
...
8 bits

CLUSTER TABLE (INCOMING)

NEXTHOP	POINTER (TO LINK-PREFIX TABLE)
...	...
32 bits	17 bits

CONFLICT TABLE

POINTER (TO LEFT CHILD)	POINTER (TO CLUSTER TABLE (OUTGOING))
...	...
15 bits	17 bits

FIG. 21B

ALGORITHM

Procedure: CAST_Forward_Packet(Packet packet)
Upon receiving an unicast packet this procedure is called in a CAST router

begin

nexthop ← CTI[packet.cluster_no_incoming].nexthop

pointer_link-prefix table ← CTI[pointer_cluster_outgoing].pointer_link-prefix_table

pointer_cluster_outgoing ← Search_link-prefix_table(pointer_link-prefix_table, 0, packet.destination, PT, CT)

cluster_no_outgoing ← CTO[pointer_cluster_outgoing].cluster_no_outgoing

Sendpacket (cluster_no_outgoing, nexthop)

end

Link Clustering

FIG. 21C

Router A

Multicast Group	Next Hop Links
224.1.2.1	L1,L3
224.1.2.3	L2
224.1.2.4	L1,L3
224.1.2.8	L3
224.1.2.9	L2

Router B

Multicast Group	Next Hop Links
224.1.2.3	L2,L3
224.1.2.5	L4
224.1.2.9	L2,L3

FIG. 22

Router A

224.1.2.4

224.1.2.3 — 224.1.2.8

224.1.2.1 — 224.1.2.9

Router B

224.1.2.5

224.1.2.3 — 224.1.2.9
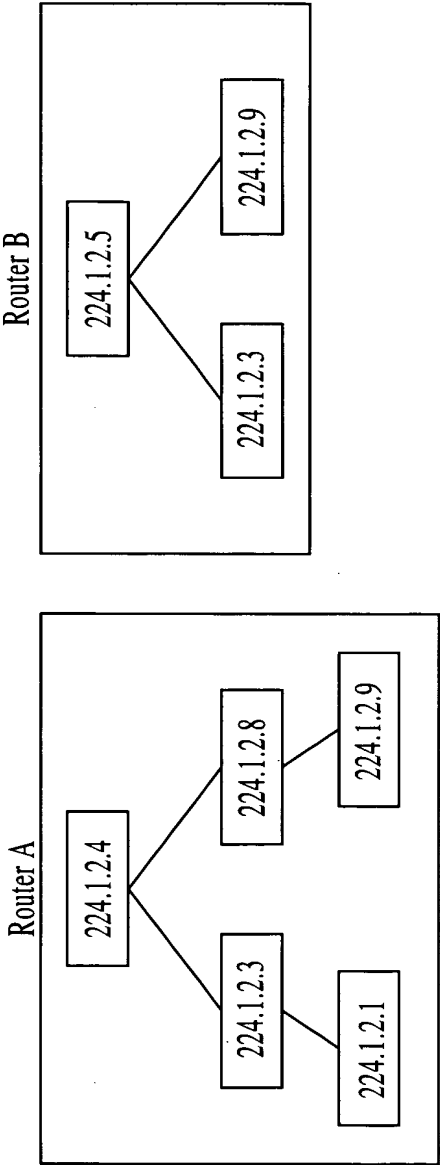
FIG. 23
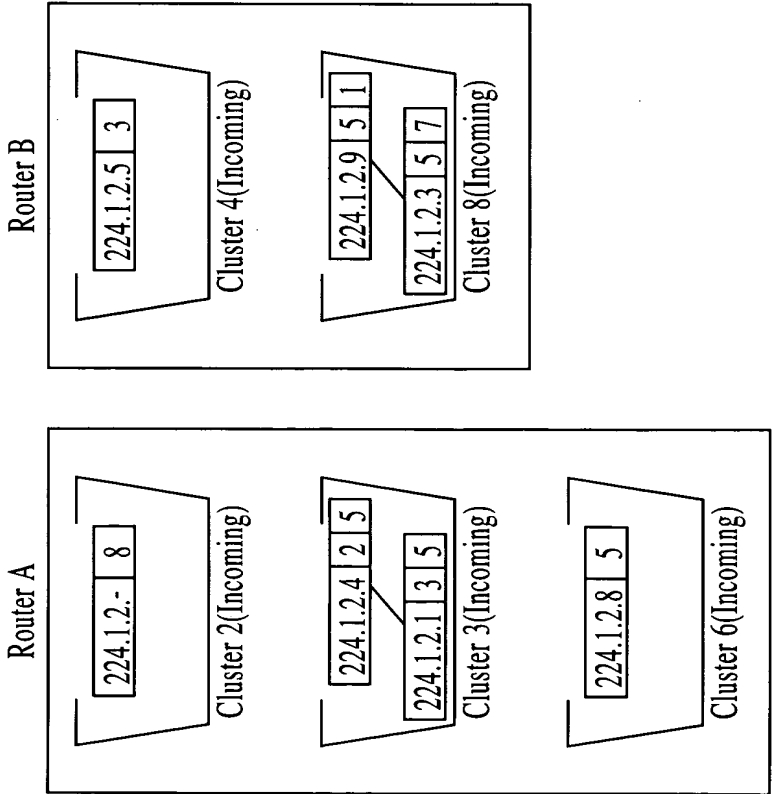
FIG. 25

Outgoing Links	Cluster No. Incoming
L1	1
L2	2
L3	3
L1,L2	4
L1,L3	5
L2,L3	6

FIG. 24

Router A

224.1.2.- | 8
Cluster 2(Incoming)

224.1.2.4 | 2 | 5
224.1.2.1 | 3 | 5
Cluster 3(Incoming)

224.1.2.8 | 5
Cluster 6(Incoming)

Router B

224.1.2.5 | 3
Cluster 4(Incoming)

224.1.2.9 | 5 | 1
224.1.2.3 | 5 | 7
Cluster 8(Incoming)

| 224.1.2.3 | 2 | Data |

L1

A

L3

L2

| 224.1.2.3 | 8 | Data |

L1

B

| 224.1.2.3 | 5 | Data |

L2

L4

L3

| 224.1.2.3 | 7 | Data |

FIG. 26

| 224.1.2.- | 8 |

| 224.1.2.3 | 8 |

| 224.1.2.9 | 8 |

FIG. 27

Cluster 1 (Incoming)

Cluster 2 (Incoming)

Cluster k (Incoming)

n/k

n/k

n/k

....

FIG. 30

Level 0

k clusters

Level [log(k)-1]
Cut Off

Level [log(n)-1]

FIG. 29

Searching Starts

FIG. 28

FIG. 31

FIG. 32

Number of Clusters (Incoming)

Memory Size (KBytes)

Extra Memory Required in CAST Patricia Trie Scheme

FIG. 33

X-axis: **Number of Clusters (Incoming) (k)**

Y-axis: **Number of Memory Accesses**

Legend:
- Patricia Trie Scheme
- CAST with Patricia Clustering

FIG. 34

FIG. 35

Number of Clusters (Incoming) (k)

FIG. 36

- Patricia Trie Scheme
- CAST with Patricia Clustering

Number of Memory Accesses

Number of Clusters (Incoming) (k)

FIG. 37

Legend:
- Patricia Trie Scheme
- CAST with Patricia Clustering

Number of Memory Accesses

Actual Implementation Results

Scheme	Lookup Power (MPPS)				
	MAE-EAST	MAE-WEST	PAC-BELL	AADS	PAIX
Patricia Trie	0.75	0.90	1.95	1.13	1.02
LPC	2.12	2.41	2.90	3.53	4.17
CAST (Patricia)	4.89	5.03	6.32	6.53	7.81
CAST (Symmetric)	0.92	1.07	2.19	1.26	1.25
CAST (Link)	0.96	1.11	2.20	1.27	1.27

FIG. 38

Multicast Results (40,000 Entries)

Scheme	Lookup Power			Memory (KBytes)	Update Time (Memory Accesses)
	Maximum (Memory Accesses)	Average (Memory Accesses)	Lookup Power (MPPS)		
AVL Tree	16	15.21	1.31	1026	15.21
Tag Switching	1	1.00	20.00	1040	15.24
IP Switching	16	2.42	8.26	1862	30.43
CAST (Link clustering, 2048 Clusters(ln.))	7	4.17	23.98	889	15.18

FIG. 39

FIG. 40

FIG. 41

Number of Outgoing Links of the Router

Compression of the Multicast Routing Table (In %)

CAST Aggregation in Multicast Routing Table
Normal Aggregation in Multicast Routing Table